State & Federal Energy Storage Technology Advancement Partnership (ESTAP)

Todd Olinsky-Paul

Clean Energy States Alliance

Thank You:

Dr. Imre Gyuk
U.S. Department of Energy,
Office of Electricity Delivery and
Energy Reliability

Dan Borneo
Sandia National Laboratories

ESTAP is a project of CESA

Clean Energy States Alliance (CESA) is a non-profit organization providing a forum for states to work together to implement effective clean energy policies & programs:

- Information Exchange
- Partnership Development
- Joint Projects (National RPS Collaborative, Interstate Turbine Advisory Council)
- Clean Energy Program Design & Evaluations
- Analysis and Reports

CESA is supported by a coalition of states and public utilities representing the leading U.S. public clean energy programs.

Clean Energy States Alliance

Sandia National Laboratories

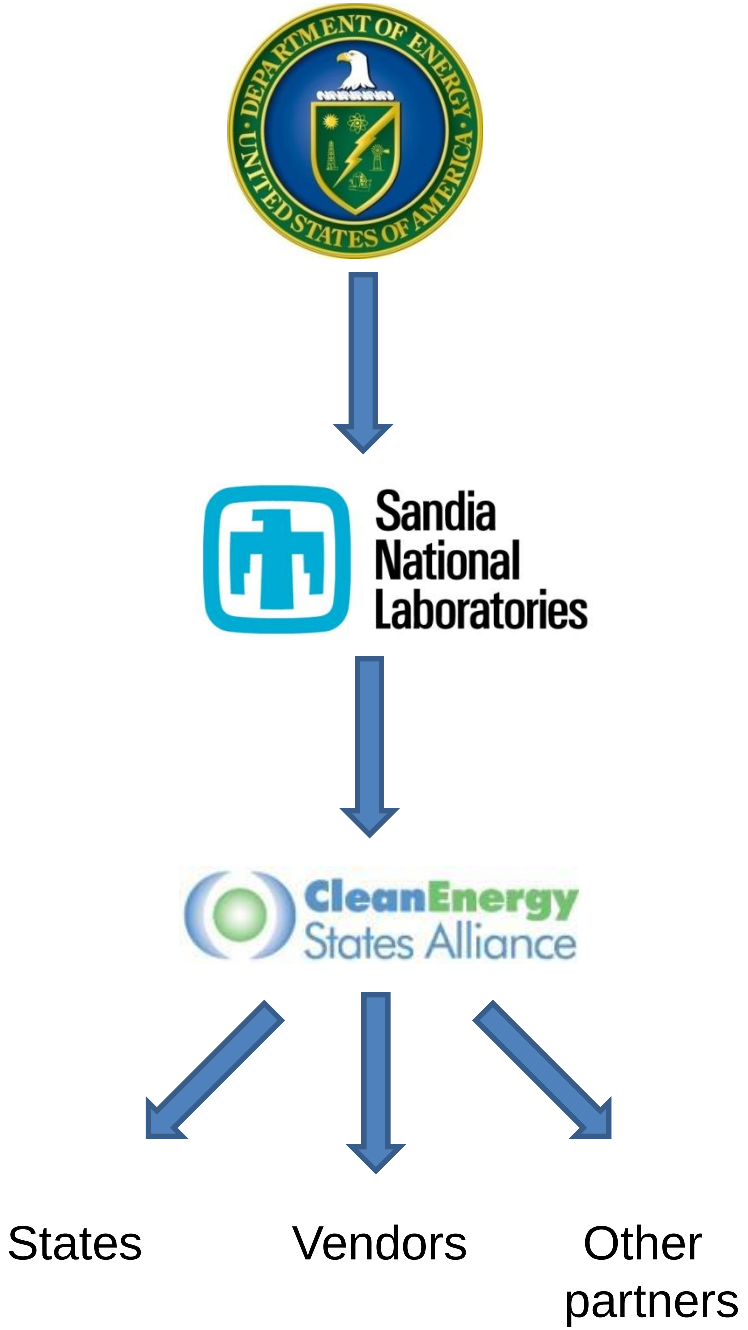
U.S. DEPARTMENT OF ENERGY

ESTAP* Overview

Purpose: Create new DOE-state energy storage partnerships and advance energy storage, with technical assistance from Sandia National Laboratories

Focus: Distributed electrical energy storage technologies

Outcome: Near-term and ongoing project deployments across the U.S. with co-funding from states, project partners, and DOE



* (Energy Storage Technology Advancement Partnership)

ESTAP Key Activities

- Disseminate information to stakeholders
  - ESTAP listserv >500 members
  - Webinars, conferences, information updates, surveys
- Facilitate public/private partnerships at state level to support energy storage demonstration project development
  - Match bench-tested energy storage technologies with state hosts for demonstration project deployment
  - DOE/Sandia provide $ for generic engineering, monitoring and assessment
  - Cost share $ from states, utilities, foundations, other stakeholders

Clean Energy States Alliance

Sandia National Laboratories

U.S. DEPARTMENT OF ENERGY

Contact Information

Project website:

www.cleanenergystates.org/projects/energy-storage-technology-advancement-partnership/

CESA Project Director:

Todd Olinsky-Paul (Todd@cleanegroup.org)

Sandia Project Director:

Dan Borneo (drborne@sandia.gov)

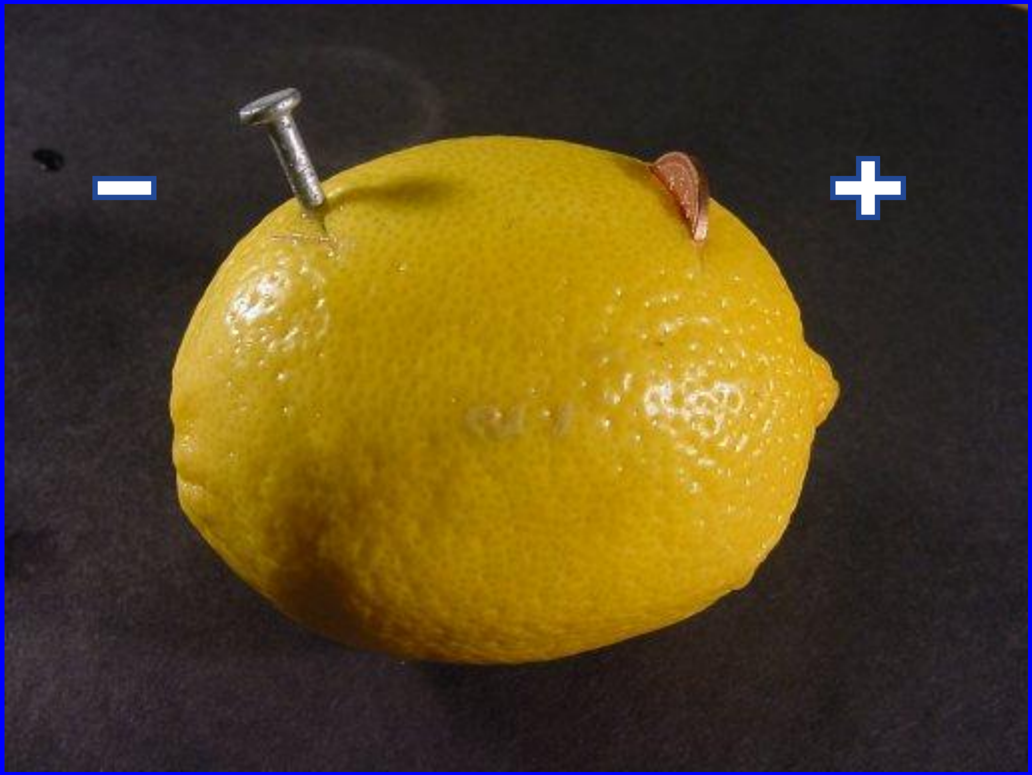
Clean Energy States Alliance

Sandia National Laboratories

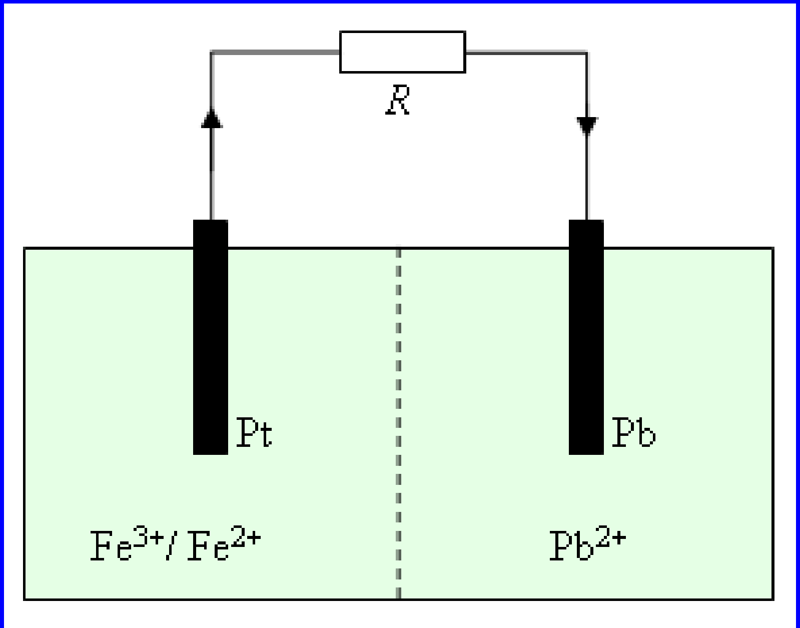
U.S. DEPARTMENT OF ENERGY

Flow Batteries for Grid Energy Storage:

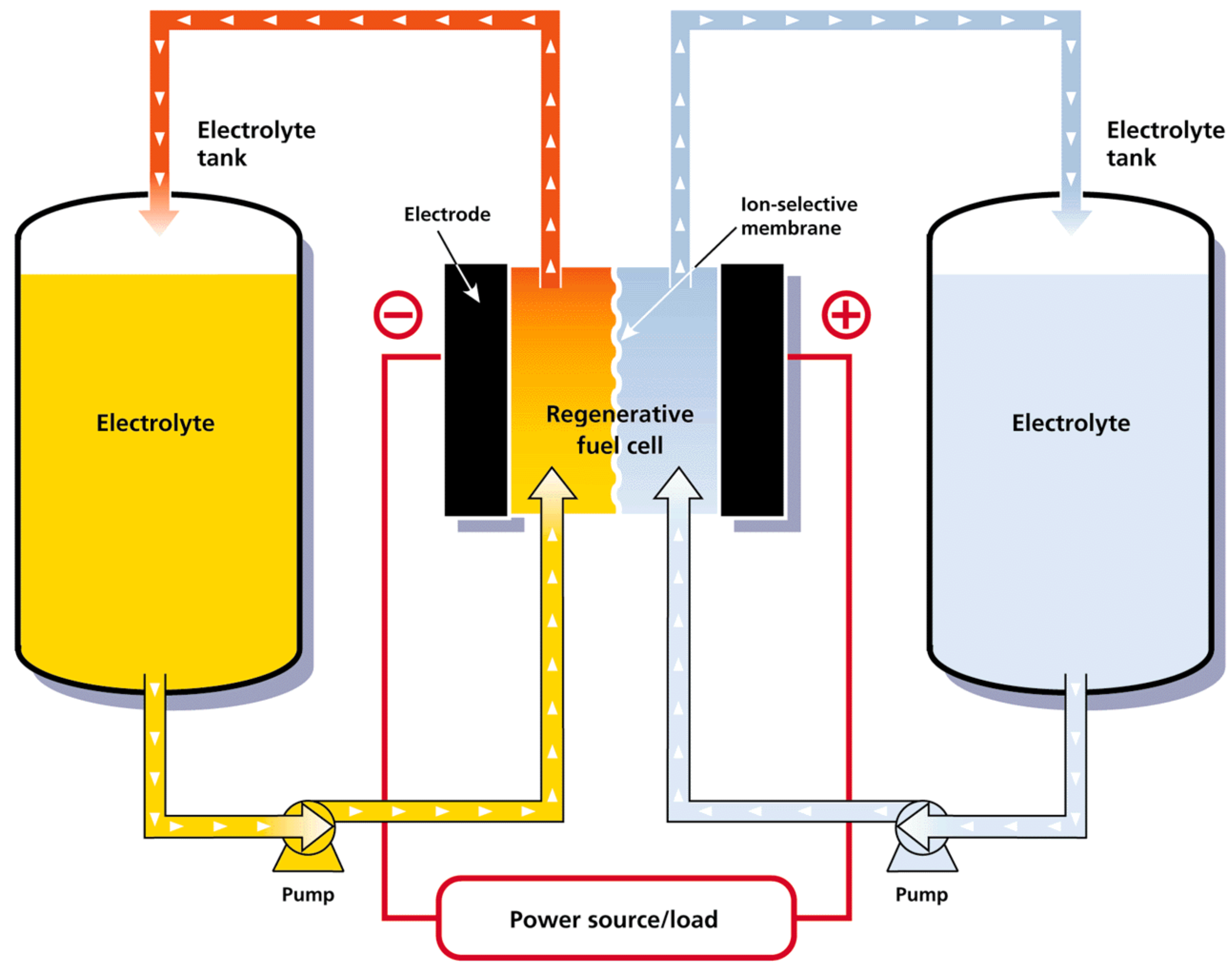
IMRE GYUK, PROGRAM MANAGER
ENERGY STORAGE RESEARCH, DOE



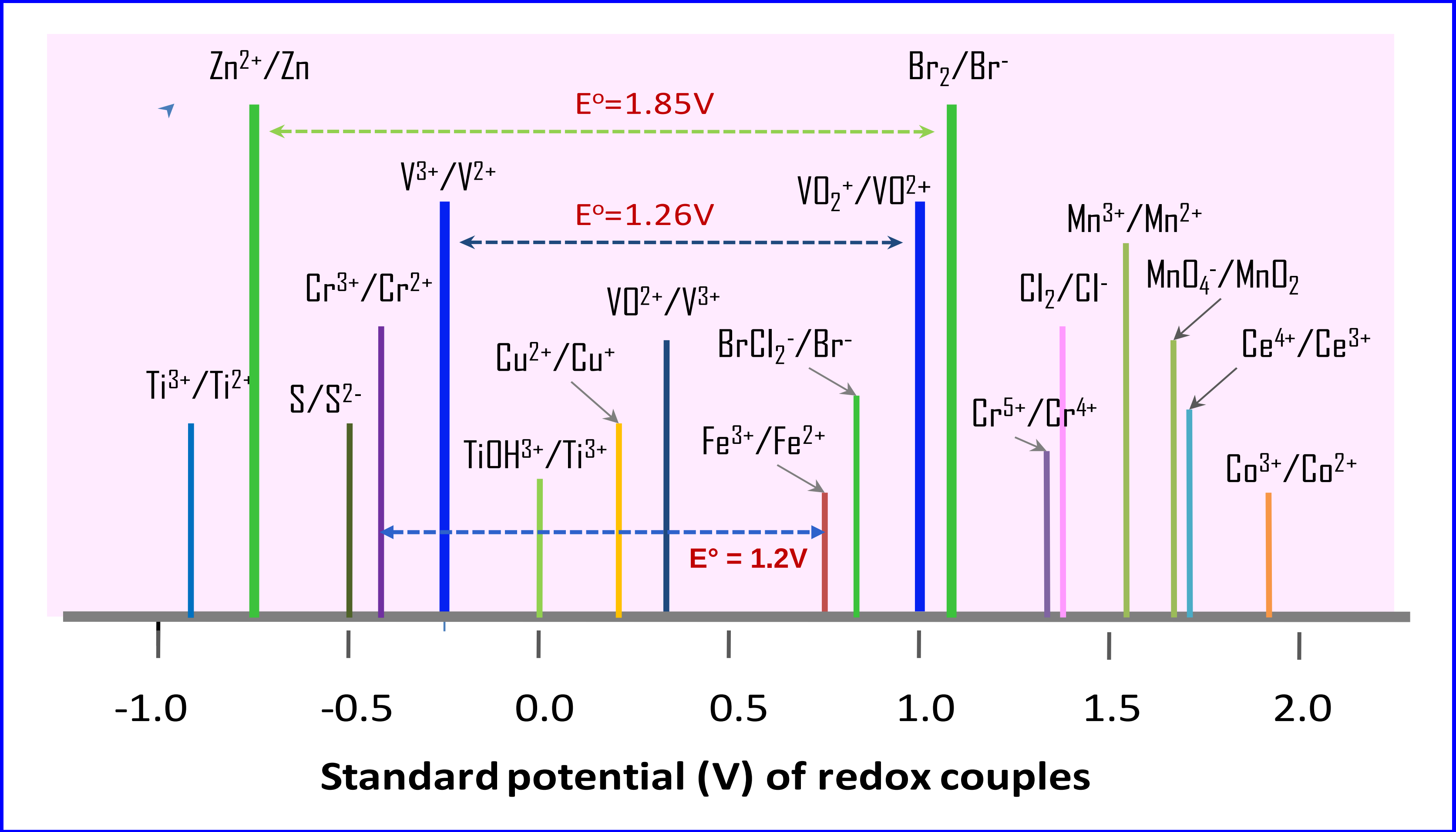
It’s easy to make a Battery: 2 Electrodes and an Electrolyte



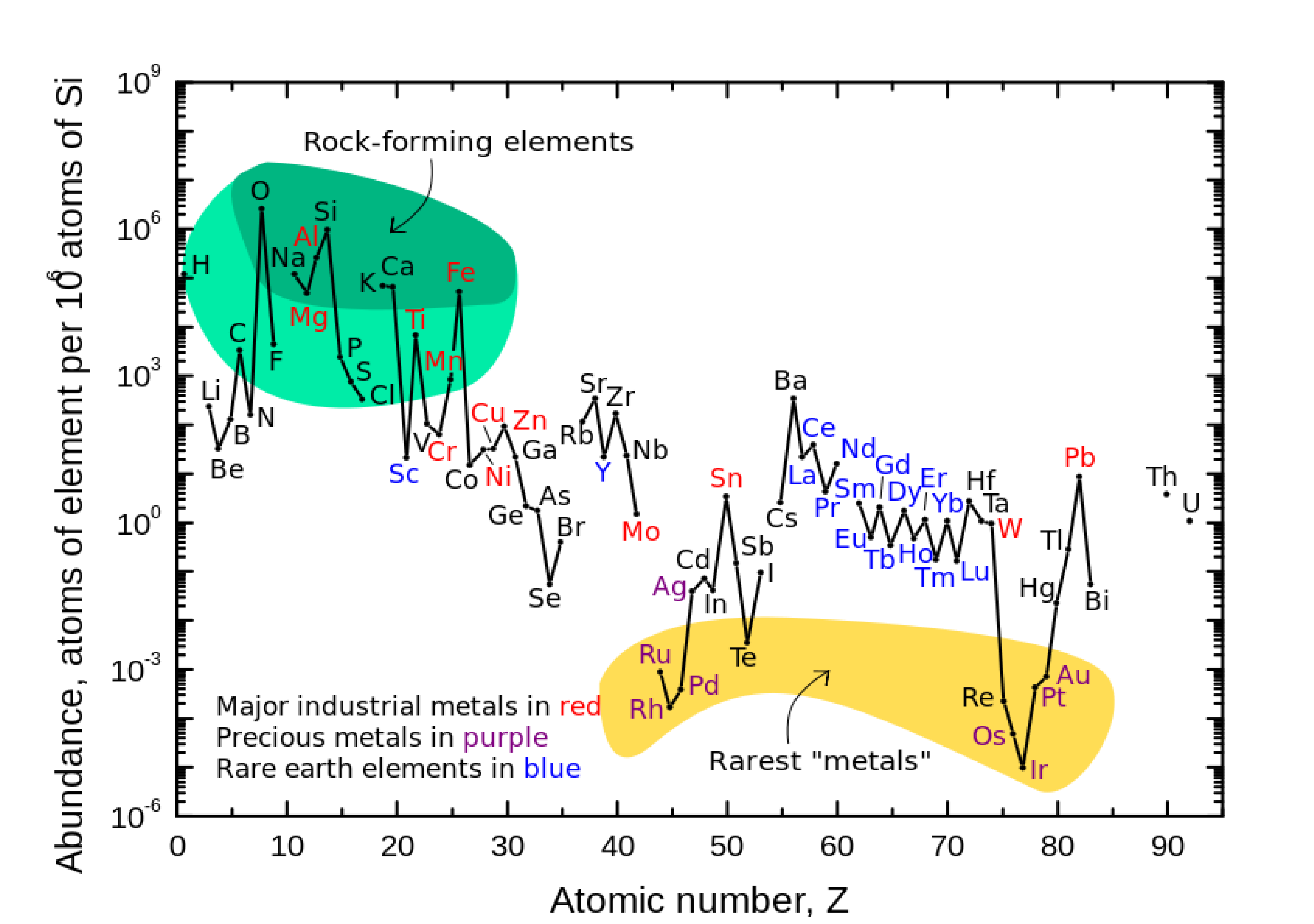
A rechargeable Battery uses 2 Half-Cells with different Electrolytes separated by a Membrane.



Power depends on the Fuel Cell, Energy depends on the Electrolyte



We want high Potential !



We want low Cost !

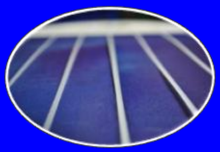
Examples:

Zn Br – Primus Power (ARRA Project)
Premium Power (ARRA Project)
ZBB (Early Demos)
Redflow (Testing at Sandia)
V-V – Prudent Power
Ashlawn (ARRAProject)
UniEnergy (Based on PNNL Research)
Fe Cr – Deeya
Enervault (ARRA Project)

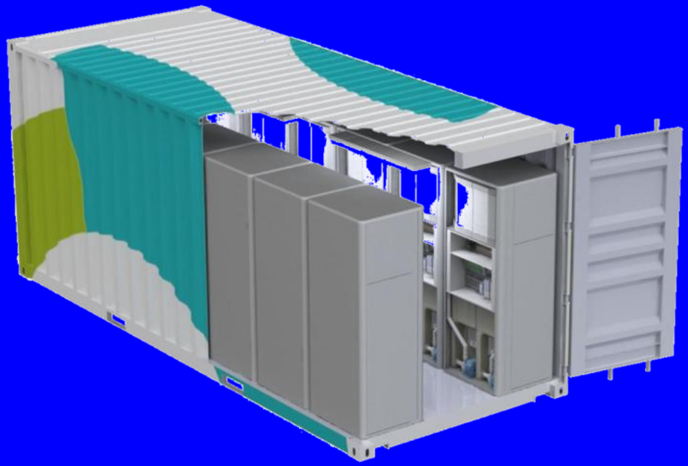
ARRA – Primus Power

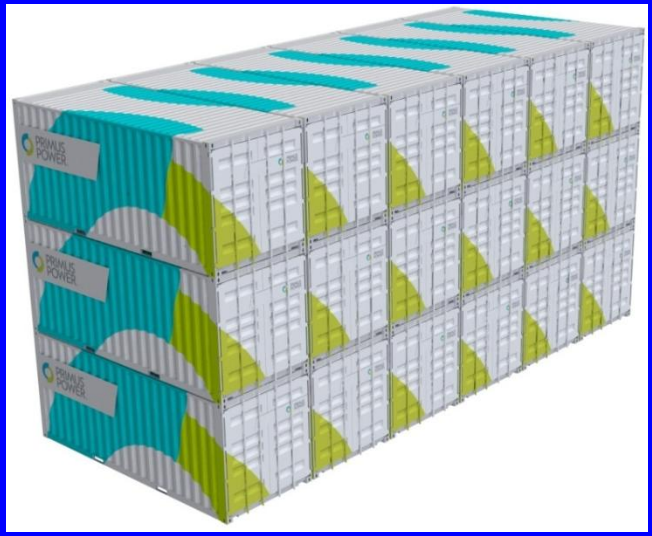
2012-TiE50
Hottest Tech Startups
2011-GoingGreen Global 200

25 MW / 3hr battery plant to firm 50MW of wind for the Modesto Irrigation District in CA, providing equivalent flex capacity to 50 MW of natural gas engines costing $73M



High power
metal electrodes





Fully self-contained, hermetically sealed flow battery modules

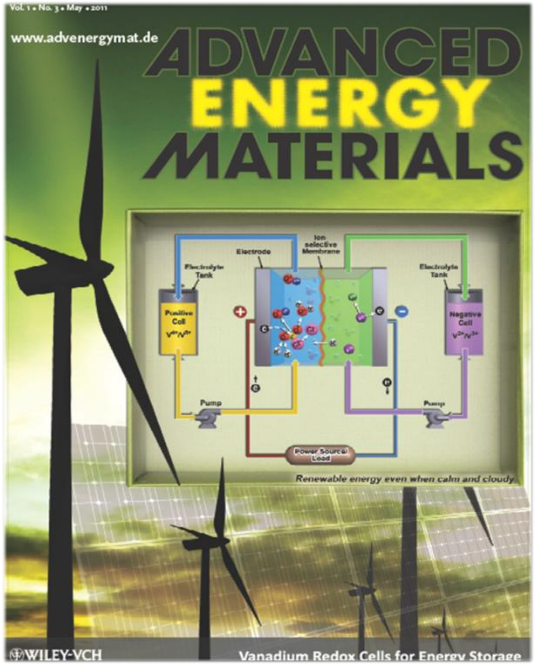
250kW/750kWh EnergyPods™

4MW/12MWh incremental “Plug & Play” deployment

Anderson *et. al.* Synthesis of Ionic Liquids Containing Cu, Mn, or Zn Coordination Cations

Sandia, Nov. 2011

PNNL, Nov. 2011



Liyu Li *et al.*, Stable Vanadium Redox Flow Battery with High Energy; 1, 394-400, 2011

Applications for Redox Flow Batteries

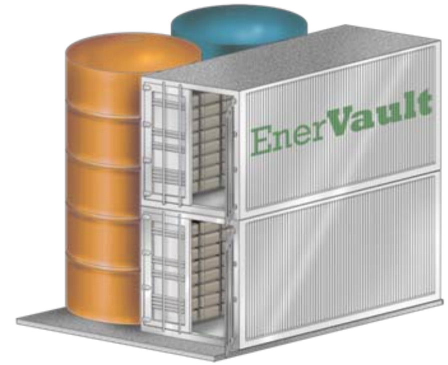
Bret Adams
Dir. Business Development

December 20, 2012

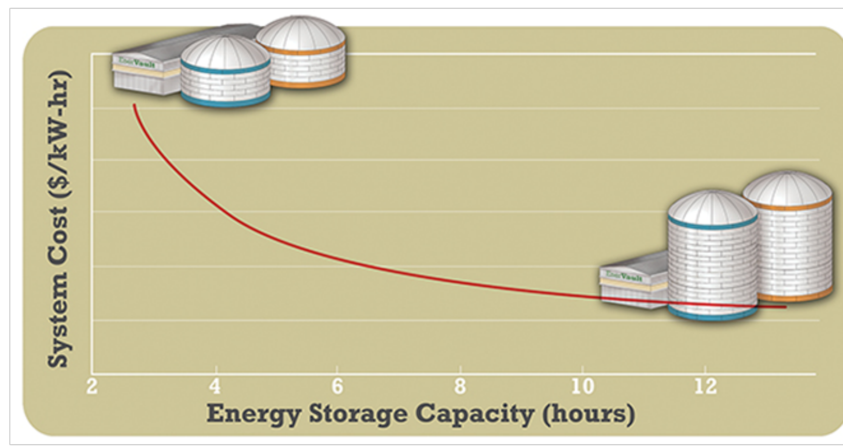
BAdams@EnerVault.com

Why Redox Flow Batteries for Grid Scale?

- Independent configuration of system power and energy
  - Application flexibility

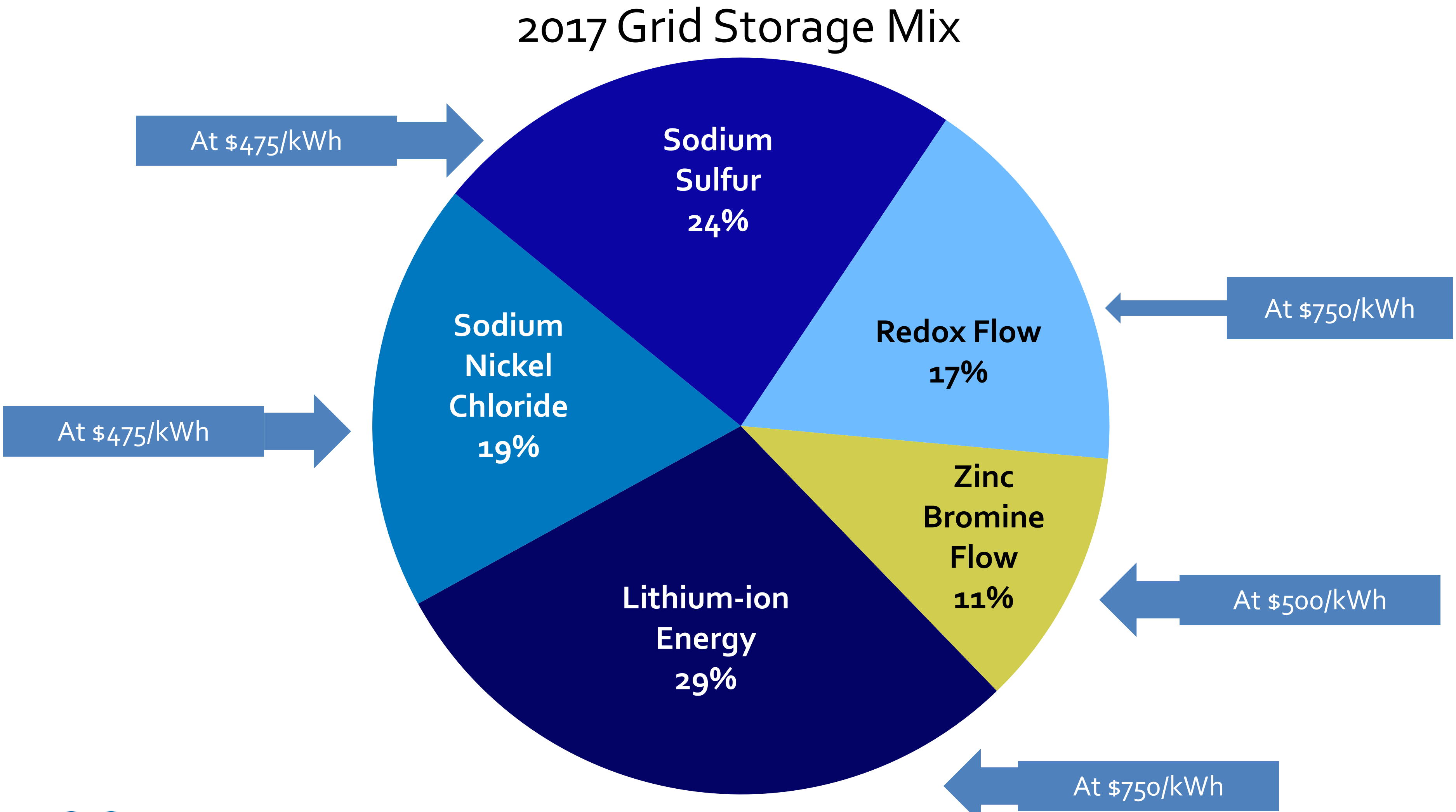


- Economics get better at higher energy to power ratio: 3 - 10 hrs
  - Peak shaving applications
  - Long duration back-up



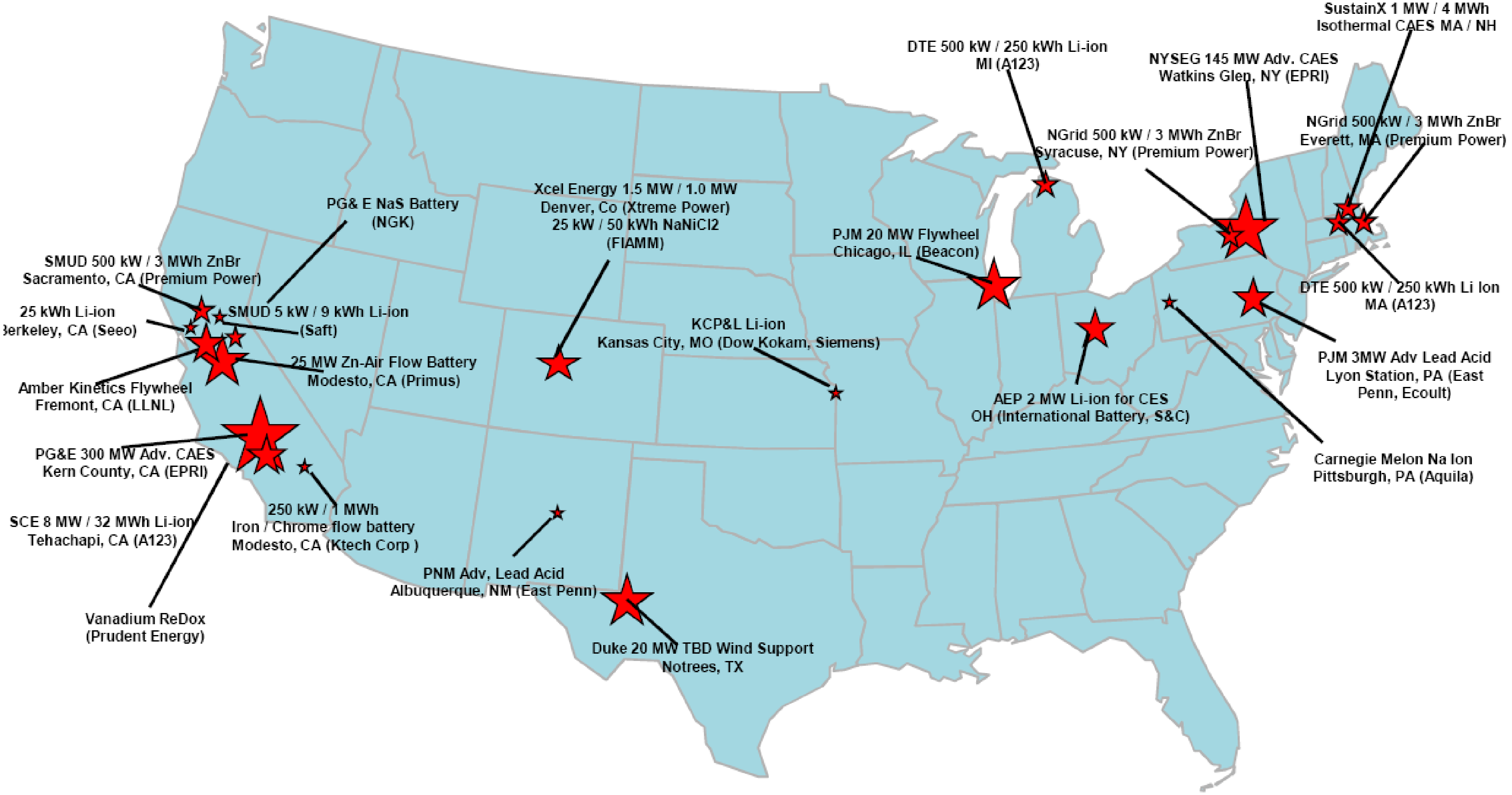
- System safety at high energy capacity
  - < 10 minutes of energy is electrically connected at any time

RFB market share will grow to a 17% market share by 2017, with the highest growth rate



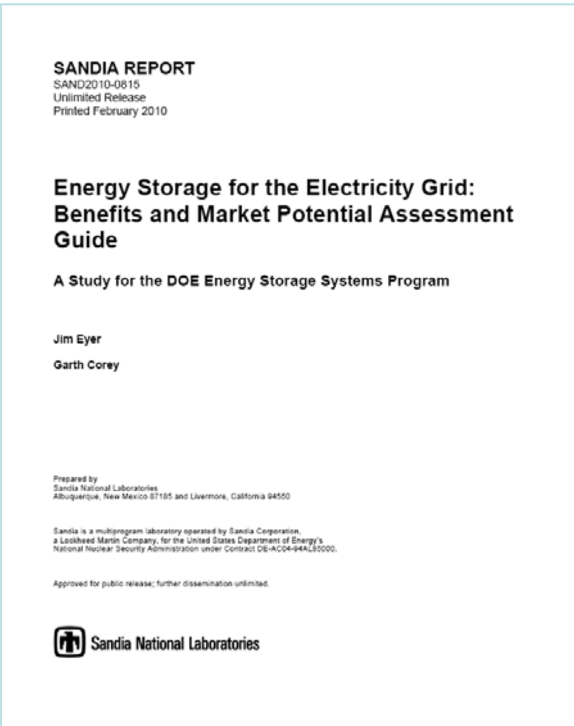
Source: Lux Research *Grid Storage Demand Forecaster, 2012*
Contact: Brian Warshay, Brian.Warshay@luxresearchinc.com

Energy Storage Demonstrations in the U.S. Planned or Under way – List is Not Complete



EPRI ELECTRIC POWER RESEARCH INSTITUTE

Utility Applications



SANDIA REPORT
SAND2010-0815
Unlimited Release
Printed February 2010

Energy Storage for the Electricity Grid: Benefits and Market Potential Assessment Guide

A Study for the DOE Energy Storage Systems Program

Jim Eyer

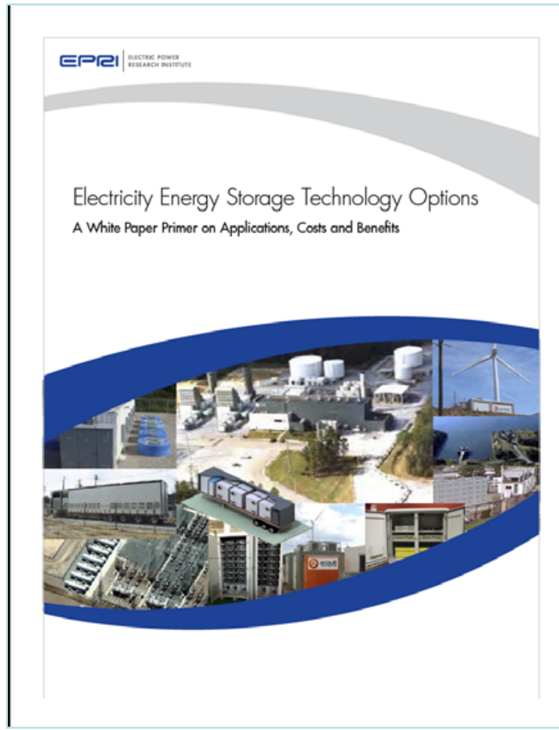
Garth Corey

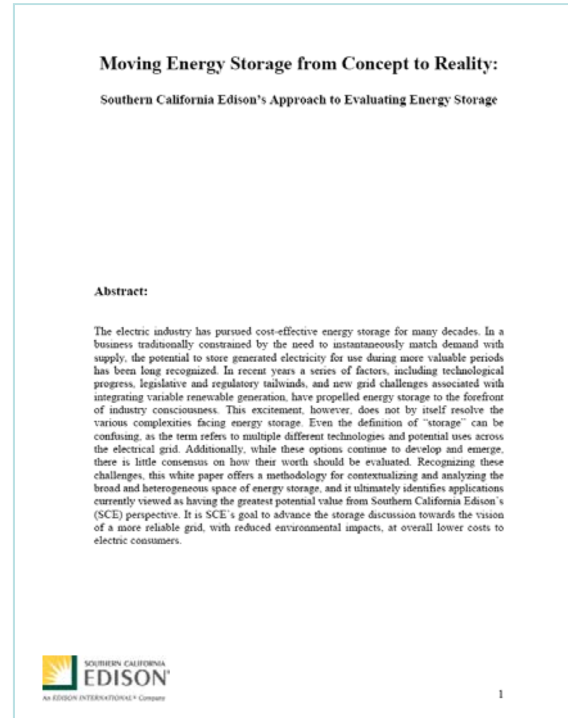
Prepared by
Sandia National Laboratories
Albuquerque, New Mexico 87185 and Livermore, California 94550

Sandia is a multiprogram laboratory operated by Sandia Corporation,
a Lockheed Martin Company, for the United States Department of Energy's
National Nuclear Security Administration under Contract DE-AC04-94AL85000.

Approved for public release; further dissemination unlimited.

Sandia National Laboratories





Moving Energy Storage from Concept to Reality:

Southern California Edison's Approach to Evaluating Energy Storage

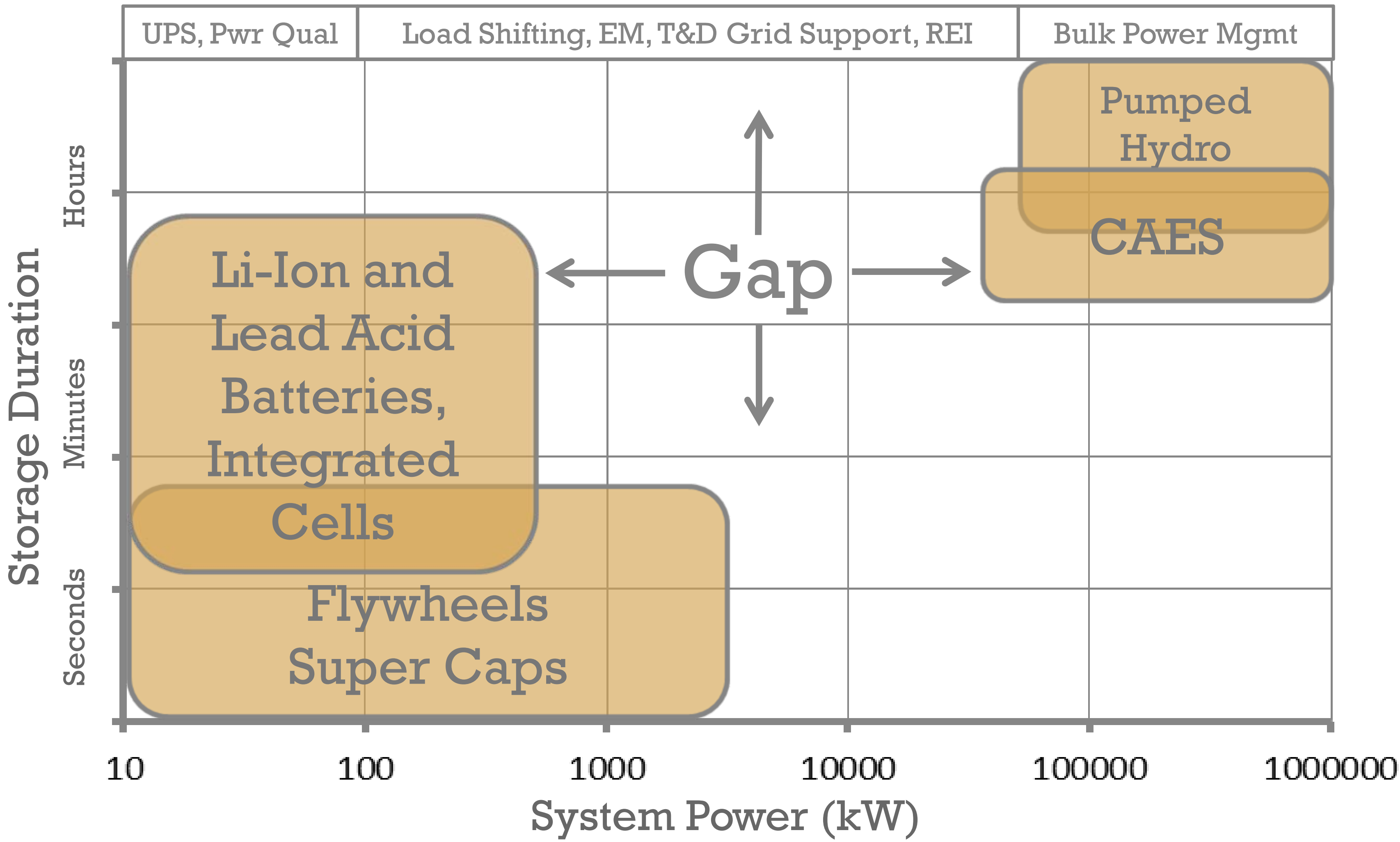
Abstract:

The electric industry has pursued cost-effective energy storage for many decades. In a business traditionally constrained by the need to instantaneously match demand with supply, the potential to store generated electricity for use during more valuable periods has been long recognized. In recent years a series of factors, including technological progress, legislative and regulatory tailwinds, and new grid challenges associated with integrating variable renewable generation, have propelled energy storage to the forefront of industry consciousness. This excitement, however, does not by itself resolve the various complexities facing energy storage. Even the definition of "storage" can be confusing, as the term refers to multiple different technologies and potential uses across the electrical grid. Additionally, while these options continue to develop and emerge, there is little consensus on how their worth should be evaluated. Recognizing these challenges, this white paper offers a methodology for contextualizing and analyzing the broad and heterogeneous space of energy storage, and it ultimately identifies applications currently viewed as having the greatest potential value from Southern California Edison's (SCE) perspective. It is SCE's goal to advance the storage discussion towards the vision of a more reliable grid, with reduced environmental impacts, at overall lower costs to electric consumers.

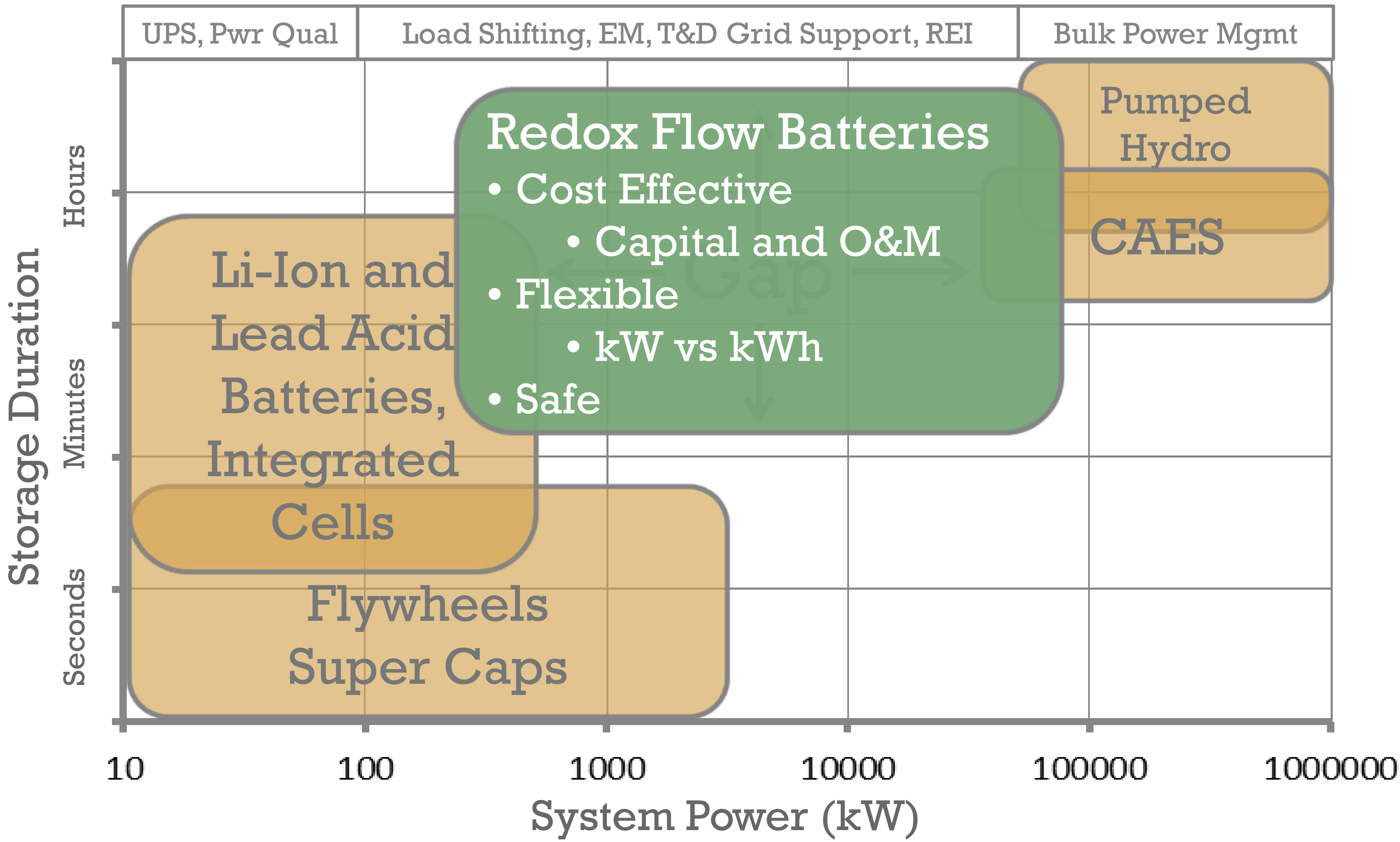
SOUTHERN CALIFORNIA EDISON
An EDISON INTERNATIONAL Company

1

Market Opportunity



RFB Fills The Gap



Conventional Redox Flow Battery

Safe

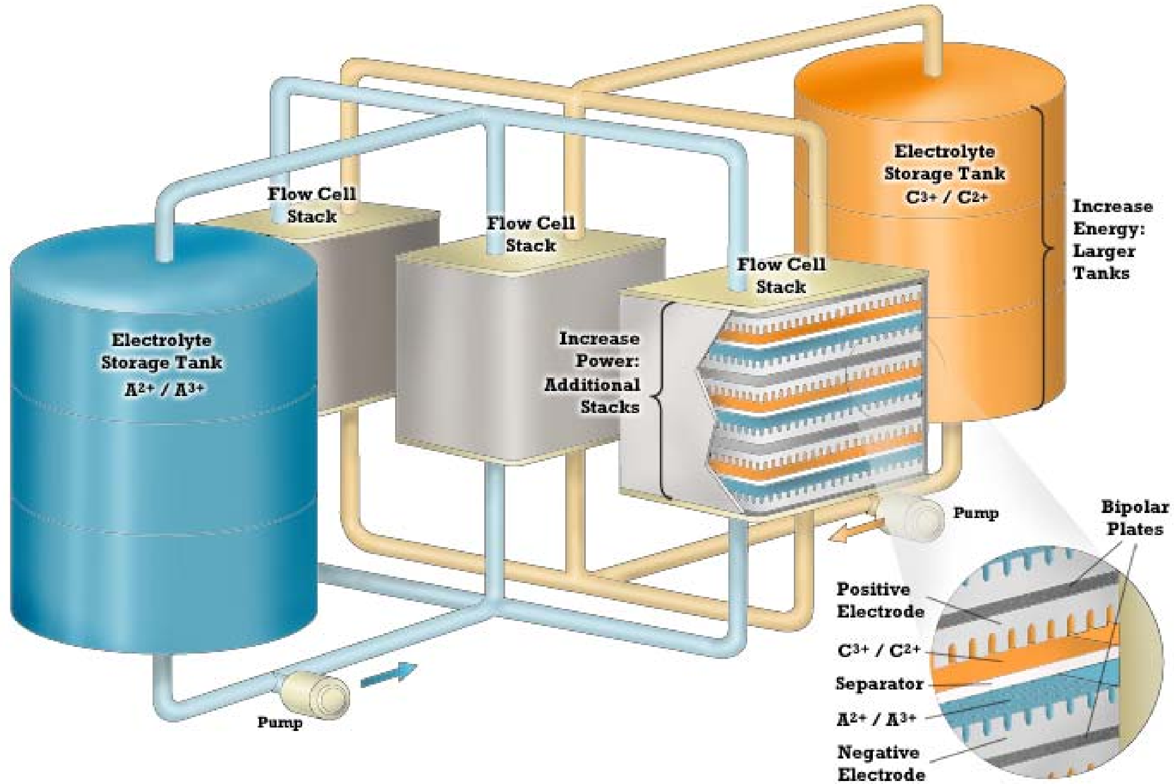
- liquid reactants
- no thermal runaway
- decoupled P & E

Long-life

- dissolved reactants

Flexible Design

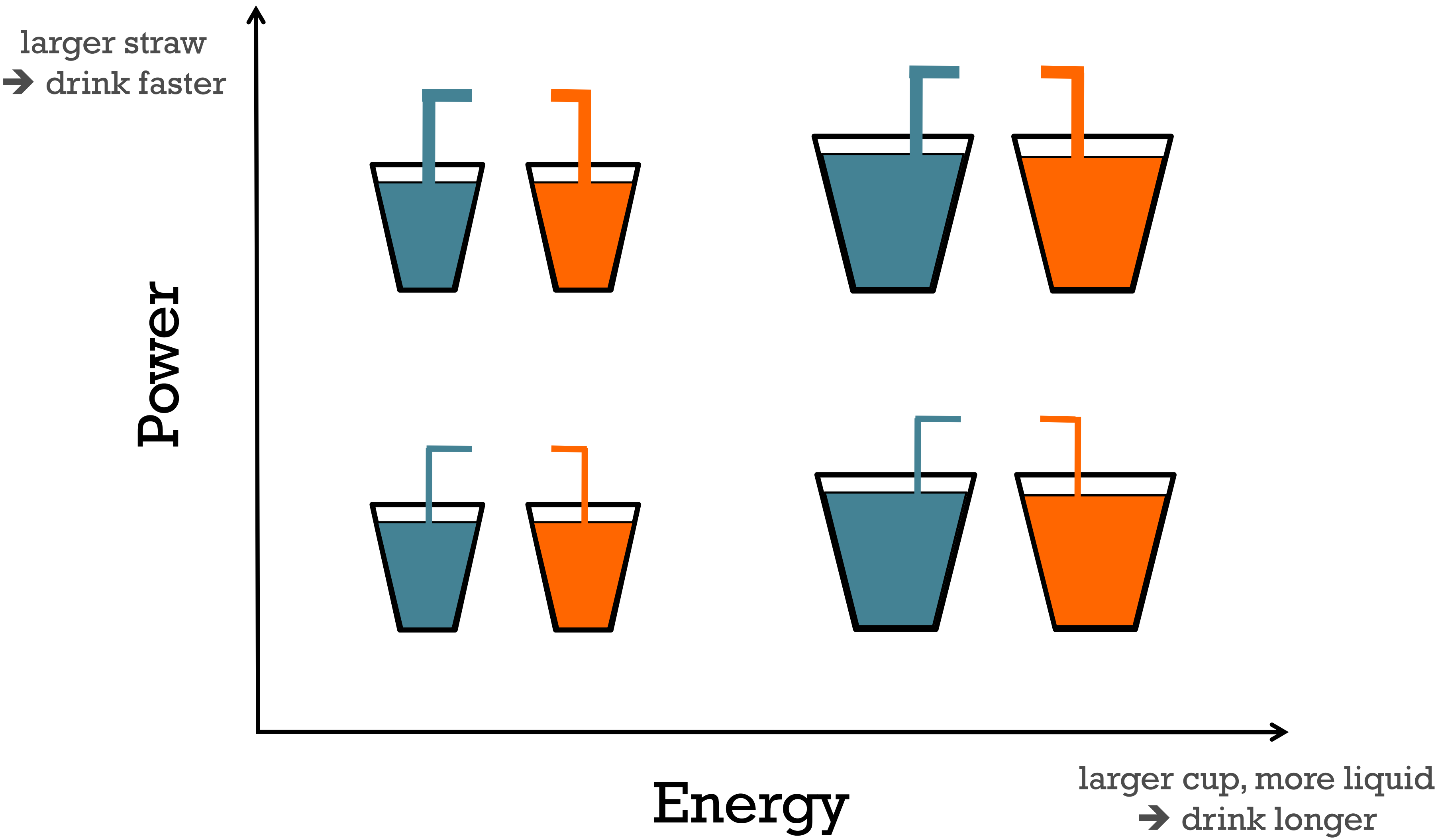
- tailored
  energy / power ratio



Chemistries

Couple	Anolyte (negative)	Catholyte (positive)
Vanadium-Vanadium	V^{2+}/V^{3+}	V^{5+}/V^{4+}
Iron-Vanadium	V^{2+}/V^{3+}	Fe^{3+}/Fe^{2+}
Iron-Chromium	Cr^{2+}/Cr^{3+}	Fe^{3+}/Fe^{2+}

RFB Design Flexibility



Utility Applications

Application	Duration hrs	Min. Power	RFB		Conventional Storage	
Wind Generation Grid Integration, Long Duration	3.5	0.2 kW	▲	$	■	$$
T&D Upgrade Deferral 90th percentile	4.5	250 kW	▲	$	■	$$$
Time-of-use Energy Cost Management	5	1 kW	▲	$	■	$$$
Renewables Capacity Firming	3	1 kW	▲	$	■	$$$
Renewables Energy Time-Shift	4	1 kW	▲	$$	■	$$$
Electric Energy Time-Shift	5	1 MW	▲	$$	■	$$$
Electric Supply Capacity	5	1 MW	▲	$$	■	$$$
T&D Upgrade Deferral 50th percentile	4.5	250 kW	▲	$$	■	$$$
Transmission Congestion Relief	4.5	1 MW	▲	$$$	■	$$$
Demand Charge Management	8	50 kW	▲	$$$	■	$$$
Load Following	3	1 MW	■	$	■	$$$
Electric Supply Reserve Capacity	1.5	1 MW	■	$$$	▲	$$
Substation On-site Power	12	1.5 kW	▼	$$$	▲	$
Voltage Support	< 1	10 MW	▼	$$$	▲	$$
Electric Service Reliability	< 1	0.2 kW	▼	$$$	■	$
Area Regulation	< 1	1 MW	▼	$$$	■	$
Wind Generation Grid Integration, Short Duration	< 1	0.2 kW	▼	$$$	▲	$
Electric Service Power Quality	<< 1	0.2 kW	▼	$$$	▼	$$$
Transmission Support	<<	10 MW	▼	$$$	▼	$$$

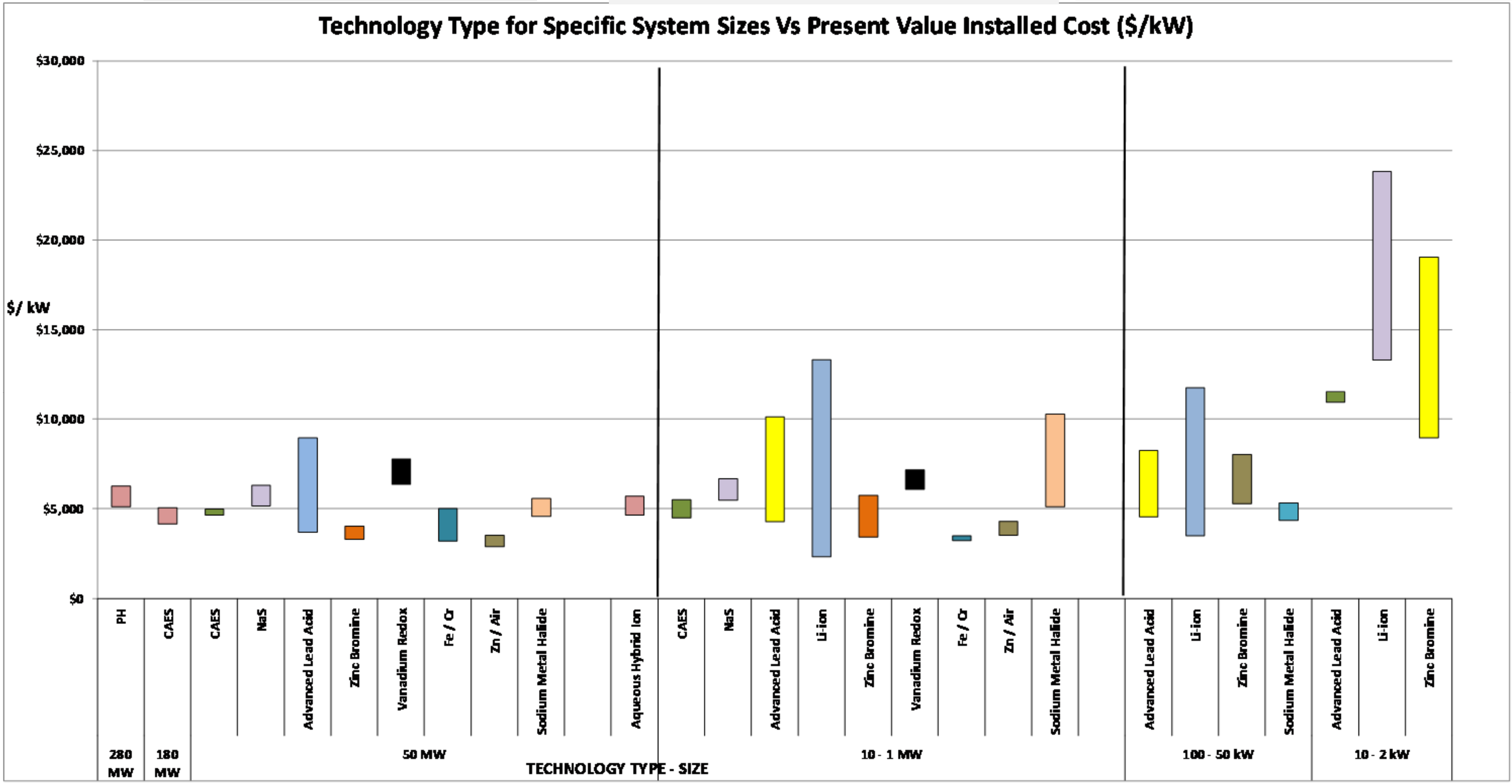
Adapted from:
Eyer, J., & Corey, G. Sandia National Laboratories, (2010). *Energy storage for the electricity grid: Benefits and market potential assessment guide* (SAND2010-0815). Albuquerque, New Mexico

▲ Ideal Application
■ Good Application
▼ Not Ideal Application

$ Good Value to Cost per kWh
$$ Med Value to Cost per kWh
$$$ Low Value to Cost per kWh

Summary-Present Value Installed Cost $ / kW

BULK ENERGY STORAGE	SUBSTATION/ FEEDER GRID SUPPORT	END-OF LINE GRID AND END-USER ENERGY MANAGEMENT



Notes: All costs in 2012$; Costs will vary significantly based on site-specific conditions;

Financials: IOU ownership; 15 year life; $30/MWH off-peak charging costs; natural gas @ $3/MBtu for CAES

Ref: EPRI 1026462 Dec 2012

Industrial Application

200kW nominal power and 400kWh storage capacity.

Courtesy Gildemeister Energy Solutions

3.3. Next Step

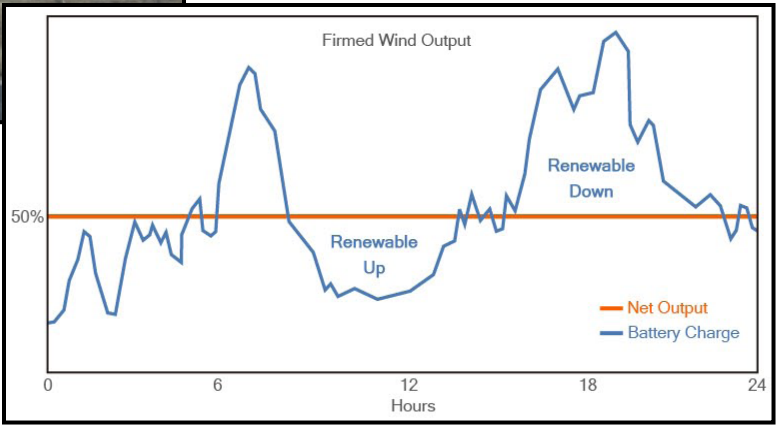
The combined system of
5MWh Vanadium Flow Battery and 100kW Solar(concentrating type)
has been constructed in Sumitomo's Yokohama Works.

Examination started last week.

1 MW / 5 MWh
Toshikazu Shibata, Sumitomo
June 2012, IFBF, Munich Germany

1000 kWh VRB-ESS® - China

CEPRI – Hebei, China
Capability: 500 kW, 1000 kWh
Commissioning date: March 2011
Application: Wind smoothing



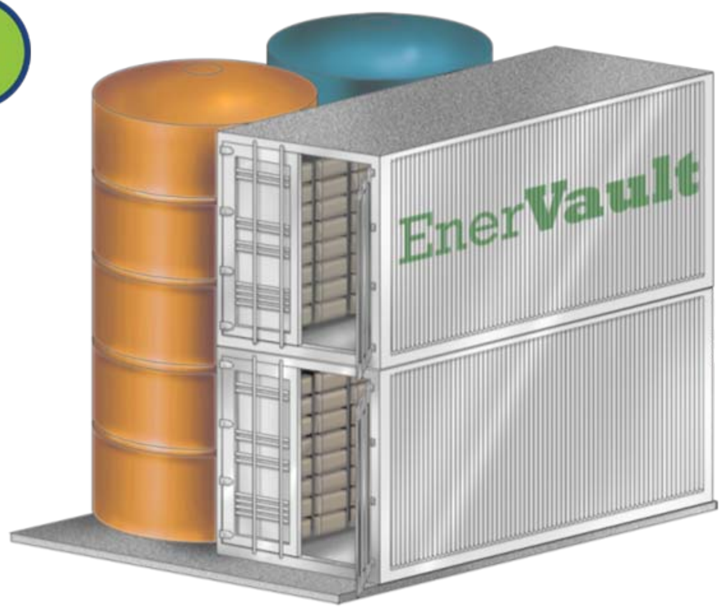
Prudent Energy
VRB® Systems

Grid Connected Flow Battery Installation Examples : Emerging Market Wireless Telecom Towers

- Emerging market telecom sites often have poor, intermittent grid electricity supplemented by diesel generators and lead acid batteries
- Deeya Energy's ESP flow batteries are operating in multiple emerging market countries to improve the cost and reliability of customers' electricity
- ~2/3 of today's installs are grid connected
- Proven value proposition in dozens of wireless telecom customer installations:
  - Up to 70% energy savings
  - < 2.5 years payback
  - Reduction or elimination of diesel generator use

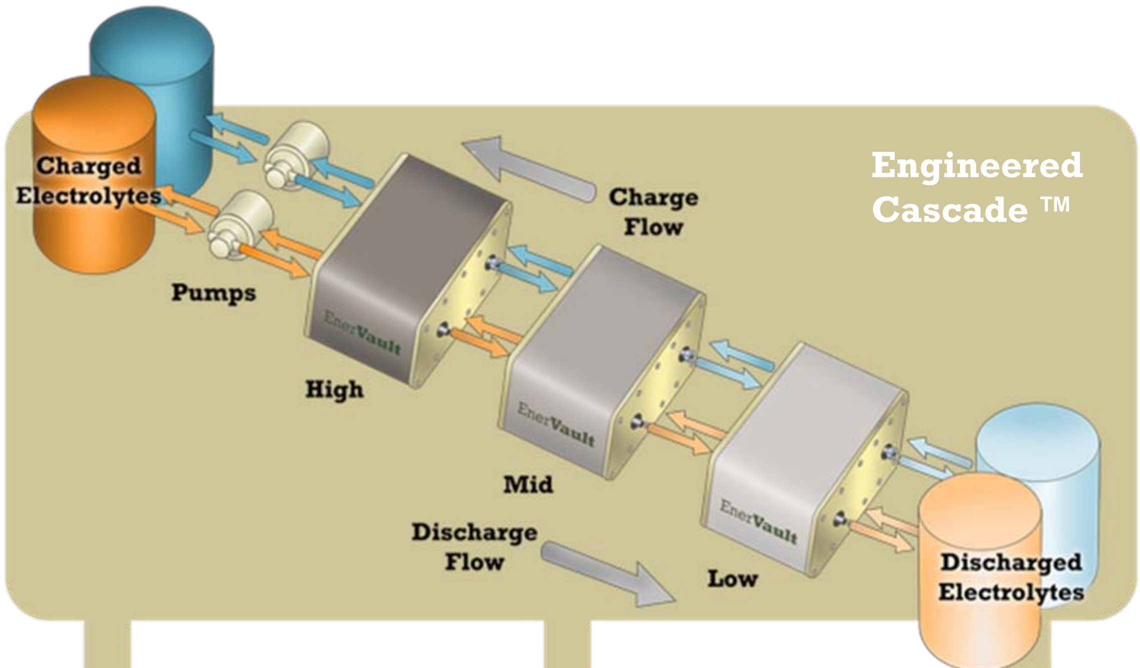
EnerVault Overview

Business	Developer of MWh-scale Redox Flow Battery (RFB) Systems for: 1) **<u>Commercial & Industrial</u>**: Peak Demand Management 2) **<u>Wind & PV PPA</u>**: Time-shift and intermittency 3) **<u>DoD</u>**: Micro-grid and energy security 4) **<u>Utility & IPP</u>**: T & D deferral and renewables integration
Investors & Awards	Total S.A., Mitsui Global Investment, 3M Corporation, Tokyo Electron, Commercial Energy, Oceanshore Ventures, U.S. Invest; DOE, CEC, NYSERDA



- Power: 250 kW & higher
- Energy: 1 MWh & higher
- Fully integrated system
  - AC to AC
  - DC (PV/wind) to AC
- Scalable to 10s and 100s MW

Engineered Cascade™ Benefits



- Decoupled Power & Energy
- Non-Volatile Electrolyte
- Fault Tolerant System
- Minimal Personnel & Environmental Hazard

Safe Storage

- Durable and Proven Materials
- Steady-State Operation
- Reduced System Complexity
- Simplified PCS

Reliable

- Reduced Pump Losses
- Low-Cost, High-Efficiency PCS
- Inexpensive Materials
- Unlimited Electrolyte Life

Cost Effective

✓ US Patent No. 7,820,321

DOE ARRA Storage Demonstration Project

EnerVault

Raytheon Ktech

JKBENERGY
CAPTURING THE POWER OF NATURE

250 kW / 1000 kWh (4 hr)

located near Turlock, CA

http://www.youtube.com/watch?v=iBgENqVLJLs

"… multi-megawatt energy storage solutions using—and I have no idea what this is—vanadium redox fuel cells… that's one of the coolest things I've ever said out loud."

President Obama, February 22, 2011

CleanEnergy States Alliance

EnerVault
Safe, Reliable, Cost-Effective Energy Storage

Thank You

www.enervault.com